A GIS Analysis of Industrial Pollution in Hartford, Illinois

Richard T Masse, MPH
University of Illinois at Springfield, Springfield, IL

Abstract

This project used geographic information system (GIS) software to create an additional tool for the assessment of industrial pollution by oil refineries near residential areas in southwestern Illinois. The study site was in Hartford, Illinois, which has a population of approximately 1,700. Indoor air, groundwater, and soil gas data from the site were obtained from state agencies and were used to generate point, polygon, and contour coverages of the study area using ArcView 3.0a and ArcView Spatial Analyst software. The resulting coverages allow investigators to assess and monitor a variety of environmental data with a new visual component. Some of the advantages of this geographical tool include corroboration of residential complaints, indication of high-risk areas, assessment of remediation actions, and validation of the need for further testing. Ultimately, this project demonstrates another way that GIS software can be used to enhance the effectiveness of environmental and public health investigations.

Keywords: environmental health, spatial analysis, ArcView 3.0a, industrial pollution

Introduction

In March of 1990 the Illinois Department of Public Health (IDPH) published a preliminary health assessment of an area in southwestern Illinois. IDPH performed this after receiving complaints from residents about the presence of gas fumes and incidences of fires in their houses. Residents voiced additional concerns about symptoms such as breathing difficulties, skin rashes and lesions, bloody noses, headaches, and exhaustion (1).

The IDPH assessment concluded that high levels of petroleum products had contaminated local aquifers, soil, and air quality and that the contamination was caused by three refinery operations in close proximity to residential areas (Figure 1). A local engineering firm, Mathes & Associates, was contracted to further assess contaminated areas and implement a remediation plan for cleaning up the existing contamination and preventing future contamination. IDPH continued surveillance in the area and received complaints again from residents in 1996. Following complaints from residents in Hartford, Illinois, IDPH collected indoor air samples from eight houses four times over a two-year period.

The purpose of this project was to take the IDPH data from the eight houses in the study area, as well as the pre-existing environmental data, and create electronic geographic coverages using geographic information systems (GIS) to aid in further analysis of the study area using a new geographical component.
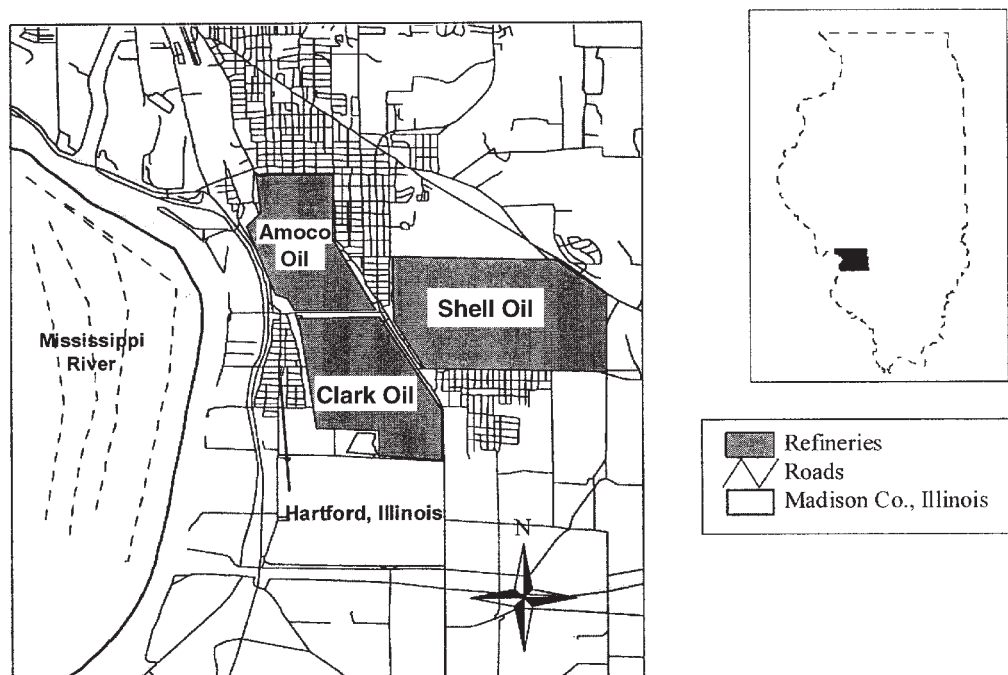
Figure 1 Hartford, IL, study site.

Data and Data Collection

The data selected to be GIS-coded for this project included demographic, air, groundwater, and soil gas data of the study area. These data came from a variety of sources including IDPH, the Illinois Environmental Protection Agency (IEPA), the Illinois Department of Natural Resources (IDNR), and the Mathes & Associates engineering firm in St. Louis, Missouri.

All of the usual demographic data of the study area were obtained, but the demographic data of particular GIS concern were the addresses of Hartford residents who complained to IDPH and had indoor air samples taken in 1996. IDPH would have liked to obtain more samples from the area, but was limited by funding and was also denied access to some buildings by reluctant citizens (2).

As mentioned previously, the indoor air sample data corresponded with complaints made by the residents. Upon receiving complaints from residents, IDPH performed indoor air and environmental sampling in each of the concerned households. Environmental data included temperature, humidity, and carbon dioxide levels. While these data are important to the overall assessment, they were not chosen for GIS conversion. The indoor air data chosen for GIS conversion were obtained by 24-hour sampling with SUMMA cans. These samples were then sent to a private lab, analyzed for over 50 compounds, and summarized in a spreadsheet by IDPH.

Groundwater data were obtained from two sources—IEPA and Mathes & Associates. There were 49 groundwater monitoring wells in the study area around Hartford. The wells were of various depths and included both private and public wells. Groundwater sampling was performed by measuring both water levels and

hydrocarbon levels to assess the thickness of petroleum products on top of the water. The most recent groundwater data were collected from the 49 wells at five different times during 1990 (3).

One set of soil gas data was collected by Mathes & Associates in 1990. A hydraulic probe unit was used to drive and withdraw soil-gas sampling probes at 14 different locations. Samples were collected at a depth of 7 to 34 feet by a vacuum pump used to pull 1 to 5 liters of air from the ground into a collection bulb. A syringe was used to withdraw soil gas that was then injected directly into a gas chromatograph for analysis.

Supplemental data important to this project included existing GIS data for the state of Illinois. These data were contained on a two-CD set distributed by IDNR. Examples of coverages on these CDs include highways, railroad, stream, and county data.

Creation of GIS Coverages

The data for this project were in many forms and of varying thoroughness. It was the goal of this project to take all the data and create foundation GIS files that could be used for analysis, but also supplemented if future data were collected. This involved the conversion of the data from the original sources into a common software. The two software programs used for this project were Quattro Pro and ArcView 3.0a.

The demographic data were first entered into a Quattro Pro database and saved as a text file. This text file was then transferred into ArcView 3.0a using its import function. From the newly created ArcView table containing study site addresses, a point coverage was created using the ArcView function of geocoding. This function adds point locations to the map based on street addresses (4). This is the software's equivalent of pushing pins into a street map on a wall. To locate the study site addresses it was necessary to have a street coverage of Hartford that included address information. This coverage was obtained from IDNR. The final result was a point coverage showing the locations of residents who filed complaints (Figure 2).

The original indoor air data were already in Quattro Pro format but contained information for 50 different compounds. This database was reduced to contain 11 compounds selected by IDPH. The new database then had 11 compound levels for 8 houses in the study area. This database was then imported into ArcView 3.0a and linked with the previously described address point coverage. This was accomplished by using a join function in ArcView 3.0a that allows tables with similar column values to be combined into one table. The final product of the indoor air data conversion is a point coverage similar to the address coverage above but with a different data table containing the compound levels for each house (Figure 3).

Although the previous coverages described originated from a spreadsheet database, this is not always necessary. Coverages can be created directly in ArcView 3.0a by using a mouse to place points or draw lines based on an existing paper map. When a point, line, or polygon is manually placed using a mouse, a table for holding information about that addition is created. The groundwater data were coded for GIS using this technique. First, well locations from a paper map were manually placed on the computer screen and then the accompanying table was filled with data such as well identification numbers and sampling data from the Mathes & Associates reports. The final product was a point coverage of monitoring wells accompanied by a table containing petroleum thickness for each well at different points in time (Figure 4). The soil gas data
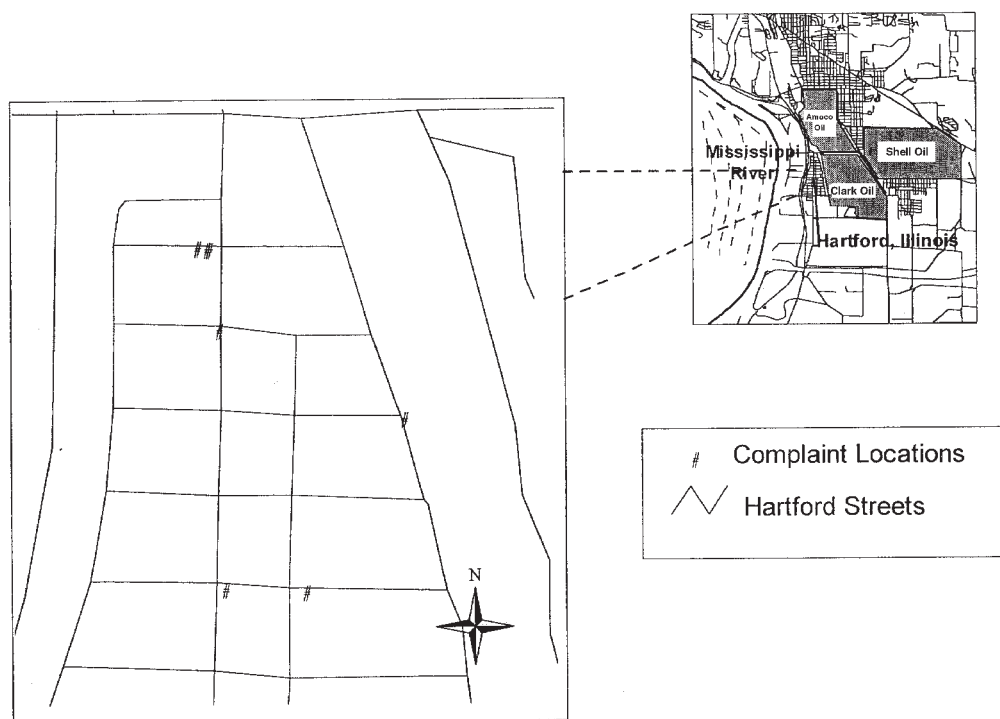
Figure 2   Point coverage of Hartford residents who filed complaints with the IDPH.
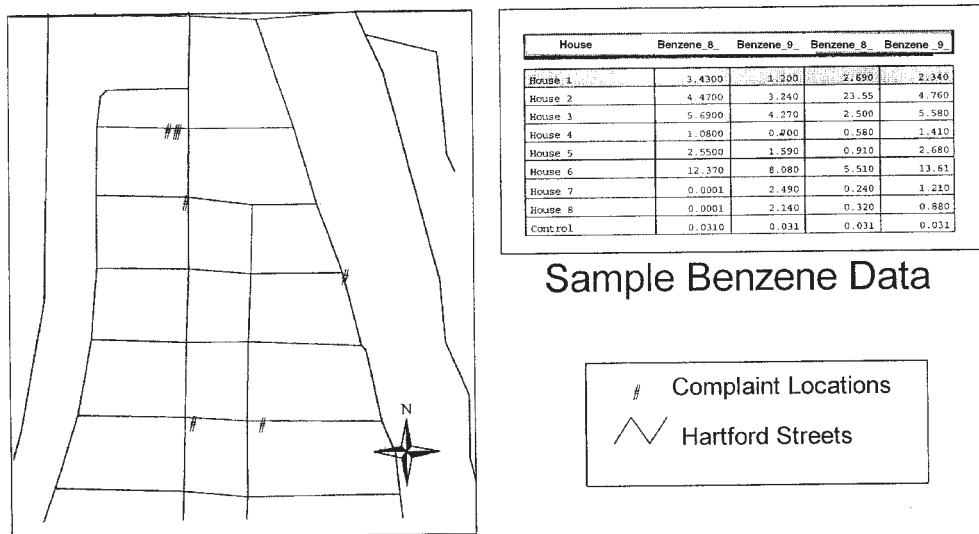

Sample Benzene Data

House	Benzene_8_	Benzene_9_	Benzene_8_	Benzene_9_
House 1	3.4300	1.200	2.690	2.340
House 2	4.4700	3.240	23.55	4.760
House 3	5.6900	4.270	2.500	5.580
House 4	1.0800	0.400	0.580	1.410
House 5	2.5500	1.590	0.910	2.680
House 6	12.370	8.080	5.510	13.61
House 7	0.0001	2.490	0.240	1.210
House 8	0.0001	2.140	0.320	0.680
Control	0.0310	0.031	0.031	0.031

Figure 3   Point coverage of indoor air sample locations, with supplemental table containing compound data for each house and the controls.

Well_name	Mar_15_9	Apr_3_90	Apr_18_9	July_18_9	Oct_18_9
B31	0.00	1.83	0.10	0.10	0.25
B34	0.90	0.00	0.35	0.90	0.03
B16	1.90	1.96	2.25	3.48	2.60
B30	0.00	0.00	0.00	1.85	1.24
B37	0.00	0.00	0.00	1.27	1.05
B7	0.80	0.36	0.80	0.00	1.05
B8	0.00	1.15	1.05	1.66	1.80
B32	0.00	1.39	1.85	5.80	3.50
RW1	0.00	0.00	0.15	0.00	0.00
RW2	0.00	0.00	0.60	0.00	1.00

*Table does not show all wells.

Monitoring Well Locations
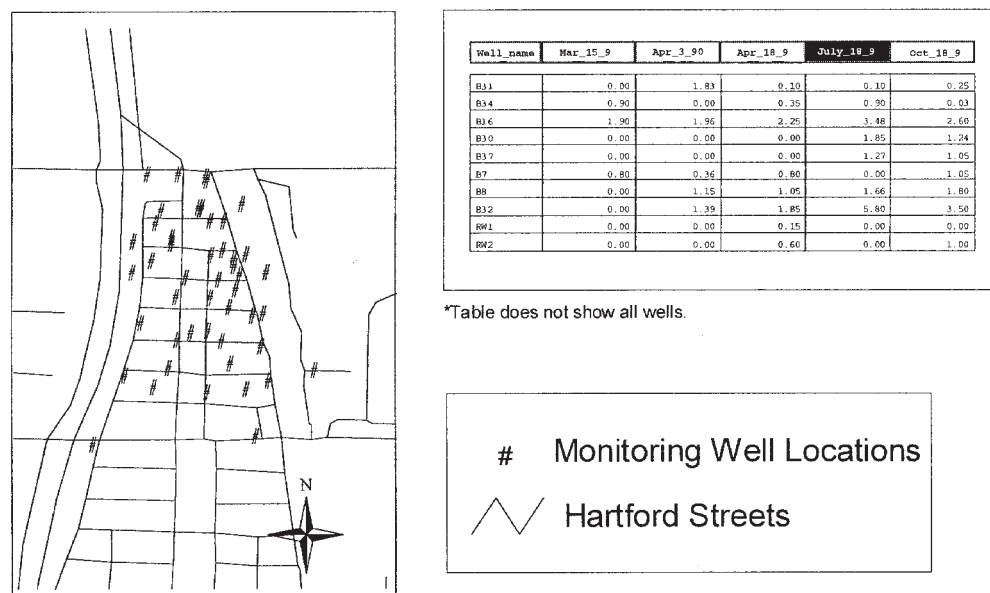/\/ Hartford Streets

Figure 4 Point coverage showing monitoring well location and supplemental table with hydro-carbon thickness data.

were converted using the same technique and resulted in a point coverage of the 14 sampling sites accompanied by a table with the corresponding data.

The point coverages created were useful for logging and searching for data concerning specific spots in the study site, but not for analyzing any spatial relationships between the individual points. A fairly new add-on software called ArcView Spatial Analyst, created for ArcView 3.0a, was used to address these issues. Specific uses to this project included the creation of hydrocarbon plume coverages to overlay indoor air and address point coverages described earlier. This type of coverage allows investigators to see the different thickness layers of petroleum products under the study site. The spatial analyst software creates such coverages by interpolating contours based on point coverage data. This specific software provided four interpolation methods, and the one chosen for this project was Spline interpolation. Spline interpolation is a general purpose interpolation method that fits a minimum-curvature surface through the input points. Conceptually, it is like bending a sheet of rubber to pass through individual points, while minimizing the total curvature of the surface. It fits a mathematical function to a specified number of nearest points. This method is best for gently varying surfaces such as elevation, water table heights, or pollution concentrations and, therefore, was applied to some of the data collected for this project (5).

The indoor air samples collected were in response to community complaints, and as a result, the samples were not appropriate for analyzing the whole study site with this software. The groundwater and soil gas data, however, were collected at strategic locations for the purpose of such analysis and therefore were good candidates for the spatial analyst software. The groundwater and soil gas point coverages described above provided the input points for creating contour (plume) coverages.

From the point coverages, the spatial analyst used Spline interpolation to create surface coverages of hydrocarbon thickness for the groundwater, as well as the gas levels for selected chemicals from the soil gas data. From the surface coverage, a contour coverage was generated but with some negative interpolations. The negative interpolations were removed, as were any contour lines for which no data existed. The resulting coverage was the contours of plumes representing hydrocarbon levels underneath the study site. Eight coverages and tables were created, including those for groundwater and soil gas data (Figure 5).
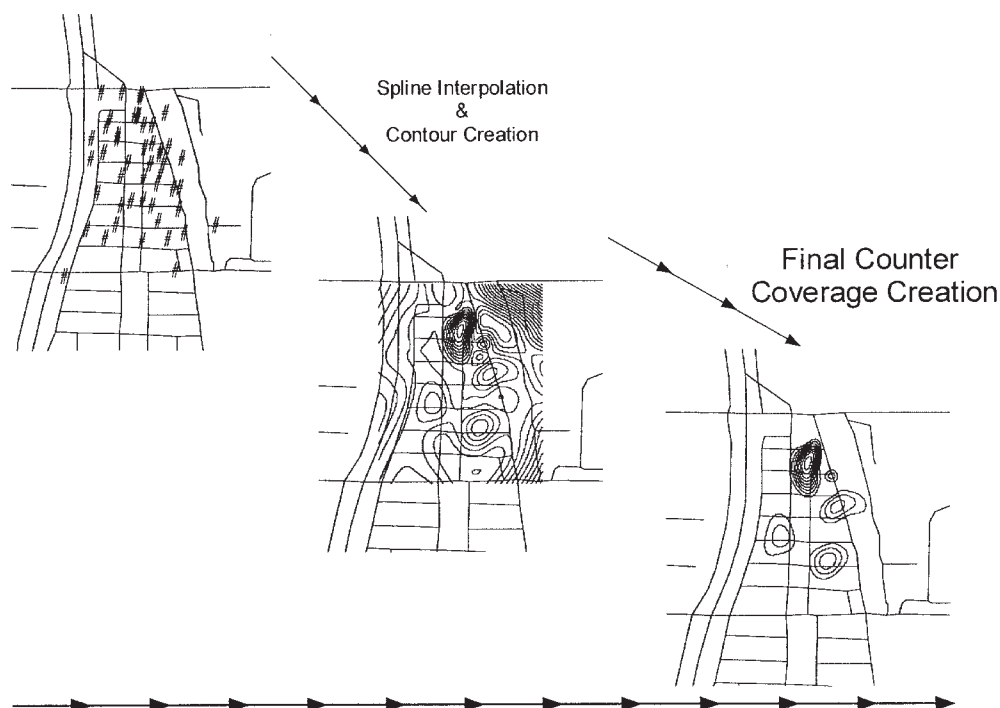

Figure 5   Creation of plume contour coverages.

Lastly, a polygon coverage showing the refinery boundaries was created directly in ArcView 3.0a. This coverage can be seen in Figure 1.

Use of GIS Coverages

Because coverages created for this project can be viewed using most GIS software, a health professional with the appropriate software and coverages can manipulate all of the past data about the study area. For this project, that included demographic data, indoor air data, groundwater data, and soil gas data. For example, an investigator who was new to the study site could use the address coverage to see where prior testing had been performed and what the results were. Also, any new testing sites could be added to the existing point coverages.

The air data could be used to view an individual house's sampling data with a simple click of the mouse; or, an investigator could view how one chemical affected all the houses sampled over a period of time. ArcView 3.0a has graphing built in, so one could view benzene levels, for example, to determine which house or houses may be at higher risk, as well as the time frame for exposure. From a simple graph, an investigator could better decide whether or not to proceed with exposure assessments on household members. This tool could be used in the field as well as in the office.

The most interesting aspect of having all the coverages created for this project was the ability to overlay the different types of data. For example, by overlaying the air sample point coverage and the hydrocarbon plume coverages, an investigator could see if the complaints of residents were corroborated. Figure 6 shows how the plume lies directly below the houses that registered complaints. Because the data sets were taken at different points in time, it was difficult to draw any conclusions using them, but one can see the utility of such coverages if the data were concurrent.
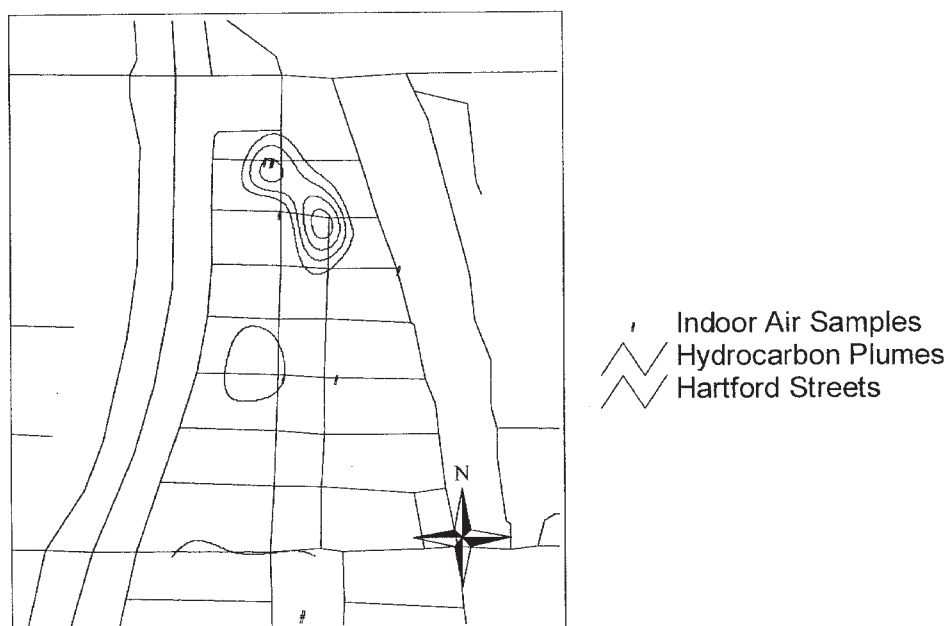

Figure 6   Air sample locations and plume coverage.

From the plume coverages alone, an investigator could learn about any plume movement. Figure 7 shows three plume coverages for three different testing times in 1990. Just by viewing the coverages, an investigator can see plume thickness and movement. This could aid in remediation actions or point out possible exposure points.

Again, all of the coverages and tables created can be manipulated. This means an investigator can add new data points, new data, and create new plume coverages based on such data. The coverages created by this project provided a framework for future GIS work on this particular project site in Hartford.
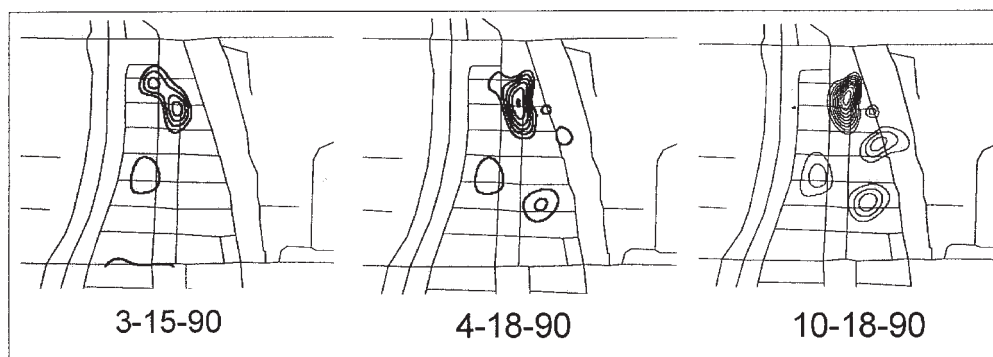
Figure 7   Tracking of 1990 hydrocarbon plume data.

Conclusion

GIS is a powerful public health tool that can only get stronger with time. Some issues that need to be addressed to expedite this growth include easier access to software, more refined software, and increased conversion of environmental and public health data into GIS form.

The software used for this project costs approximately $2,000. While this may not be a lot for some budgets, it will often be considerable for slim public health budgets. Costs can also rise if an organization wishes to run a UNIX-based system. Interagency sharing of data and software can cut back on these kinds of problems. For example, in this project, IDPH had minor GIS capability compared with IDNR or IEPA. It was only with cooperation between these agencies that data were obtained and software was made available. Once GIS's potential is fully recognized in the public health arena, we may see room made in agency budgets for such work.

Another issue that arises when using GIS for public health is the capabilities of the existing software. Because most of the past use of GIS has been by geographical and natural resource-based groups, the software is not tailored for public health investigations. The statistical power of GIS software is weak, and this is limiting for public health users (6). A public health investigator would be better off doing statistical analysis in a different software such as SPSS, SAS, or Excel. One good attribute of the ArcView 3.0a is that data are readily compatible with the aforementioned software. Again, once GIS use in public health increases, the demand for more powerful public health software will increase and so should the reality of such software.

Data are always the key to using GIS. Most projects will only be limited by the type and amount of data they possess. The process of data collection, conversion, and maintenance is a full-time job but is necessary for the success of GIS projects. Again, the time and financial hurdles can be minimized through data sharing and communication between agencies using GIS.

Specific to this project was the fact that there were not enough data or sufficient up-to-date data to make any solid conclusions about the site at Hartford, Illinois. One could, however, compare these data with past studies done on the site using similar data to see if similar trends could be observed. For this software to be useful to this project in the future, more air samples and concurrent groundwater samples are

needed. This will require agency funding and community cooperation, both of which were poor for this site study.

Even though the data sets were limiting for this site, it provided a testing ground and classroom for how GIS coverages can be used as yet another tool in health assessments.

Acknowledgments

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